PHOTONUCLEAR PRODUCTION OF THE THERAGNOSTIC AGENT ^{47}Sc FROM NATURAL Ti TARGETS

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ABSTRACT

Theragnostic medical radioisotopes have been of growing interest in the past decade, as they boast the ability to both allow diagnostic imaging as well as localized treatment of tumors. Scandium-47 is an example of a theragnostic, with ideal gamma-ray (159 KeV, 100%) and beta-particle emissions ($E_{avg, \beta-}$ =162 keV) suitable for both diagnostic SPECT imaging and therapeutic applications in cancer treatment. The photonuclear production of ^{47}Sc is being developed at Argonne National Laboratory. Natural Ti targets are irradiated (40 MeV, 3 kW, 10-12 hrs) and radioisotopes of Sc (^{46,47,48}Sc) are isolated using DGA resin. Subsequent analyses of the ^{47}Sc product with high purity germanium detectors (HPGe) and inductively coupled plasma mass spectrometer (ICP-MS) revealed high chemical purity product. The product was further analyzed by DOTA (2,2′,2′′,2′′′-(1,4,7,10-Tetraazacyclododecane-1,4,7,10-tetrayl) tetraacetic acid) titrations and provides high apparent molar activity (AMA). Advantages and drawbacks of the production method will be discussed.

EXPERIMENTAL PROCEDURE

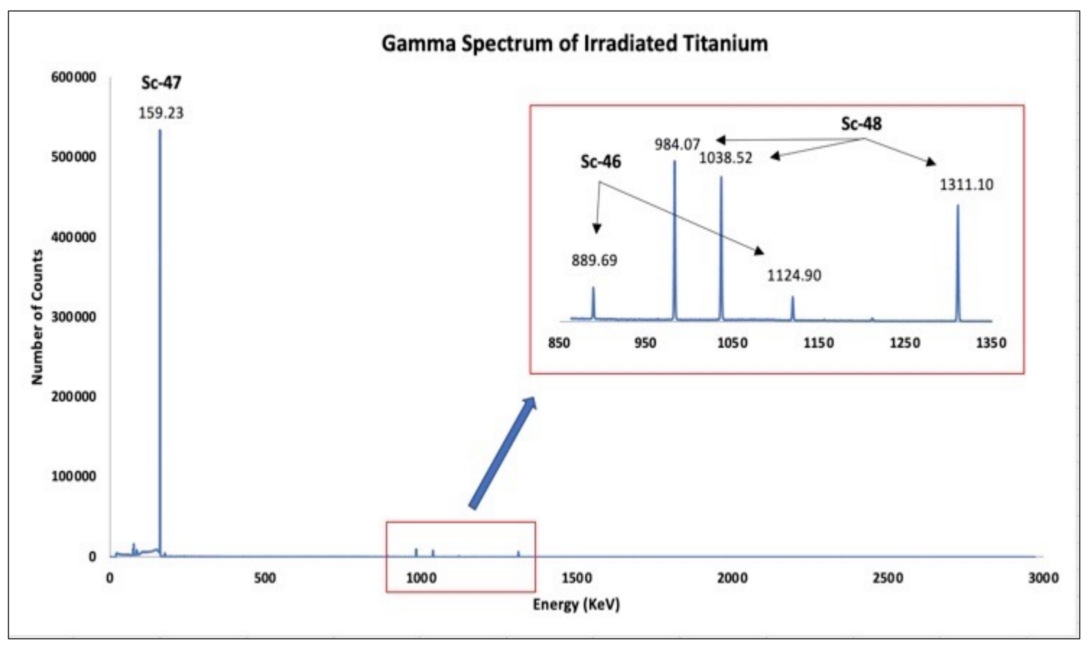
Preparation of Targets
- Ti powder (~3 g) pressed into pellets (1 g each, 3 pellets) and irradiated

Irradiation parameters
- 40 MeV, 3 kW, 10-12 hrs

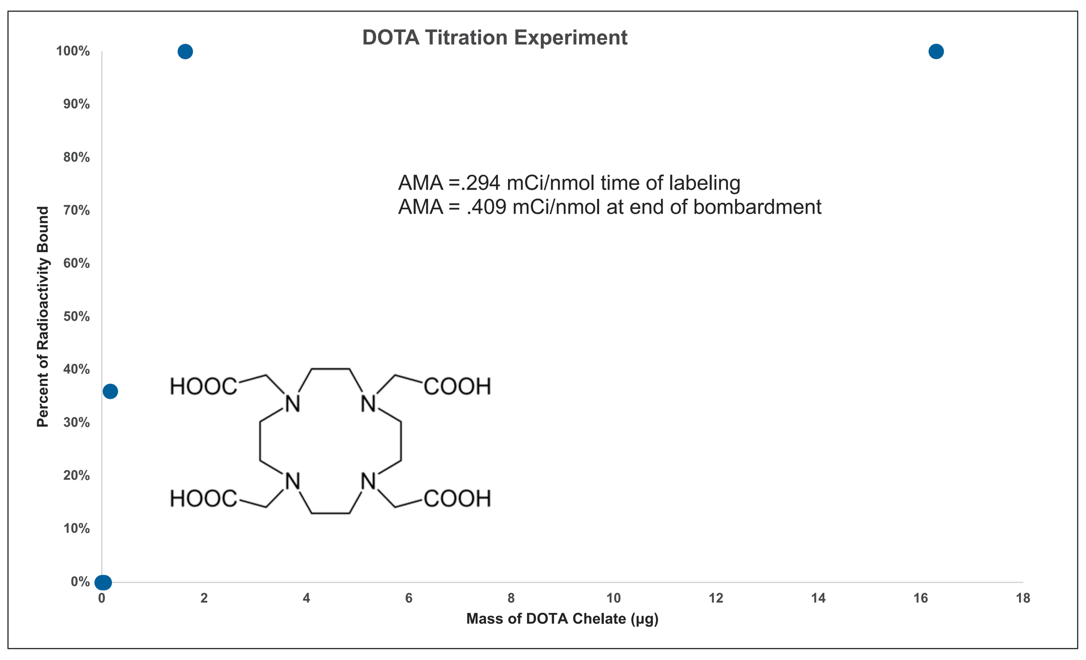
Separation of Product from Target
- Once retrieved, targets were dissolved in boiling concentrated HCl (20 mL/g $Ti_{(m)}$) and then diluted to 100 mL
- The stock solution was passed through a DGA resin – Sc was retained on the column while the Ti target material and impurities (Fe) are passed through

Purity Analysis
- The product was analyzed using inductively coupled plasma mass spectrometer (ICP-MS) as well as with high purity germanium detectors (HPGe)
- Additionally, the apparent molar activity (AMA) was determined by DOTA titrations

HPGe spectrum of purified radioscandiums from the natural Ti target



DOTA titrations were performed through increasing chelator concentrations and analyzed via Thin Layer Chromatography



ICP-MS data

Element	Al	Si	Ca	Sc	Ti	Fe	Cu	Pb
Mass (µg)	3.03	37.3	8.11	0.0357	2.69	0.645	0.136	0.0387

Specific Activity of the product was measured to be 754 mCi/µg at the end of bombardment.

*Justin is an undergraduate student in the DOE Isotope Program's Horizon-broadening Isotope Production Pipeline Opportunities (HIPPO) traineeship

TARGETRY

Natural Ti targets were used to perform demonstrations. Enriched targets will be used in the future to produce pure ^{47}Sc. However, because ^{Nat}Ti targets were used, other reaction pathways are unavoidable.

Natural abundances of Ti isotopes and photonuclear reaction reactions of interest

Isotope	Natural Abundance (%)	Reaction	Product
Ti-47	7.44	(γ, p)	Sc-46
Ti-48	73.72	(γ, p)	Sc-47
Ti-49	5.41	(γ, p)	Sc-48

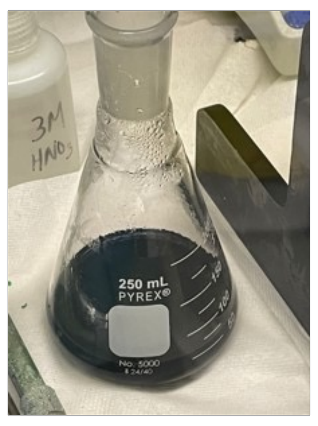
Ti metal powder was pressed into 12.7 mm pellets for irradiation (left image). Each pellet was ~1 g and 3 pellets were irradiated. Beam spots are observable on the pellets after irradiation (right image).

Ti RECYCLING

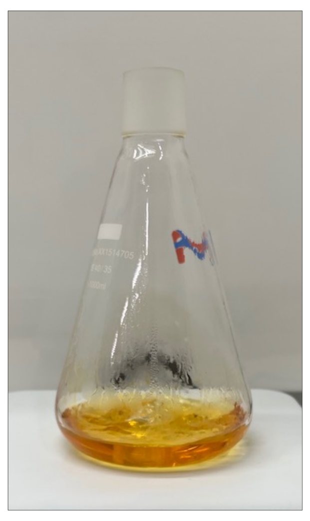
Motivation

Enriched targets of Ti-48 are required in order to produce pure ^{47}Sc. Enriched targets are expensive. Therefore, to economically produce ^{47}Sc, target material must be recycled.

Recovery of TiO_2
- 9.9947g Ti metal dissolved in boiling concentrated HCl (200 mL)
- Once dissolved and at room temp., H_2O_2 (45 mL) was added
- NH_4OH was added dropwise, TiO_2 precipitate was observed
- The precipitate was isolated via centrifugation and washed with H_2O
- TiO_2 drying and preparation
- Recovered TiO2 was heated overnight at 150 C on a hot plate to remove excess solution.
- The powder was then heated at 700 C, 2 h to remove any excess NH_4^+ salts
- The final product was subsequently weighted at 15.39406 g (92% yield).

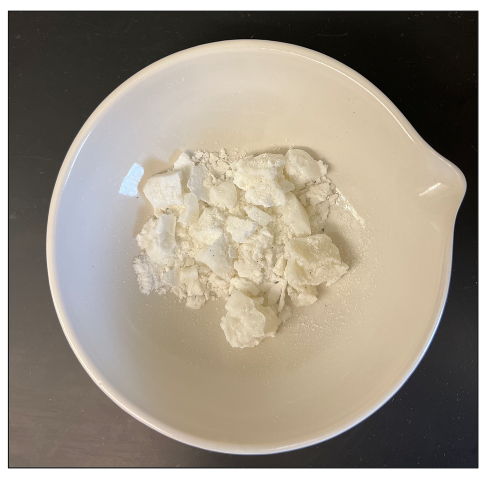


Dissolved Ti_m in conc. HCl



Solution after H_2O_2 addition

TiO_2 after centrifuge and washing



TiO_2 after drying at 700 C

FUTURE PLANS

Scandium-47 production
- Enriched Ti-48 targets to reduce Sc-46 and Sc-48 impurities
- Larger targets for more mass
- Longer irradiation period
- Higher beam currents

Reduction of the recovered Ti-48 oxide and Ti-48 metal for the next irradiation
- Perform reduction with CaH_2 and/or Ca metal
  - CaH_2 – solid state reaction
  - Ca – molten salt process
- Demonstrate recovery and reduction with irradiated targets
- Recycle irradiated targets
- Move to enriched materials

Plans for distribution

Once the recycling procedure is perfected and enriched target demonstration are complete, prepare for test batch recipients through the DOE Isotope Program's National Isotope Distribution Center.

U.S. DEPARTMENT OF ENERGY
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